NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

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REPORT NUMBER 1104

Sonar Headphone Selection
for Optimum Target Information

by

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Naval Medical Research and Development Command
Research Project 5856 M0100.001-5001

Released by:

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Commanding Officer
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SUMMARY PAGE

PROBLEM

To improve the real-time auditory detection and aural analysis capability of passive broadband sonar systems.

FINDINGS

Recent detection performance data have shown the need for upgrading sonar headsets. Headphone measurement data on commercially available headphones have shown that headphones of more appropriate bandwidth and frequency-response accuracy are not of sealed-circumaural design. Sealed-circumaural headphones exhibit low-frequency variations with placement on the head and with deterioration of ear-cushion seal. Unfortunately, current noise levels preclude use of these more accurate types. Reduction of noise levels in sonar spaces to permit use of better headphone designs is a highly desirable solution.

APPLICATION

Advanced auditory sonar system design. Aural analysis and detection and classification headphone requirements.

ADMINISTRATIVE INFORMATION

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ABSTRACT

Several closed headsets were evaluated for use by sonar operators. Their frequency response and degree of variability were measured and compared to other headsets which were open to outside noise. The advantages and disadvantages of open and closed headsets are discussed and recommendations made.

Introduction

The task in sonar has been primarily one of detecting the presence of periodic (machine generated) energy in a background of fairly homogeneous, nearly random, sea noise. the less periodic energy a target generates, the less detectable it becomes. one solution to the problem of the target remaining undetected is to reduce all periodic energy. a more practical, less costly solution has been the reduction of only the periodic energy that currently designed systems can detect. the implication here is that, as we alter our method of detection, we may increase our ability to detect previously ignored information.

For ideal aural detection, the acoustic information received at the hydrophones should be delivered to the ear as accurately as possible so that all of the periodic energy present in the ocean is transferred. This broadband transfer of energy is essential since it is the combination of several frequencies (not necessarily harmonically related), all varying in amplitude, which provide auditory cues to the presence of periodic energy. A nonlinear transfer of energy or the transfer of only some frequencies is detrimental to detection. The weakest link in the transfer of energy from acoustic source in the ocean to acoustic signal at the ear has been the headphone.

A recent study (Russotti, 1987) showed that extending the low-frequency information downward from current low-frequency cutoffs improves broadband-detection performance in auditory sonar. This finding strongly indicates that the frequency response of sonar-headsets should be upgraded in order to accurately present the stimulus to the ear.

Although it used to be difficult to measure nonaudiometric earphones, we have developed a feasible technique, and presented data on 24 commercially available nonaudiometric headphones (Russotti, et al., 1985, Russotti, et al., 1985). Figure 1 shows an average frequency response for one of the more accurate models used in our evalutations of detection bandwidth (Russotti, 1987). This model, a Sennheiser HD 430, produced a variation of 11 dB from 40 Hz to 10 kHz.[1]

Unfortunately, neither this Sennheiser headphone, nor any of the other 10 most accurate headphones we measured, has a noise occluding headshell currently necessary in the sonar workspaces on submarines. Only one of these 11 best headsets, the AKG model K-340, appears to be of a closed-circumaural design, but it has limited noise reduction ability.

Footnote 1. Samples of this headphone have been in use at Sub School, Code 60, since 14 November 1985. Highly favorable reports on its effectiveness in aural analysis are consistent with our laboratory measurements of this headphone's accuracy.

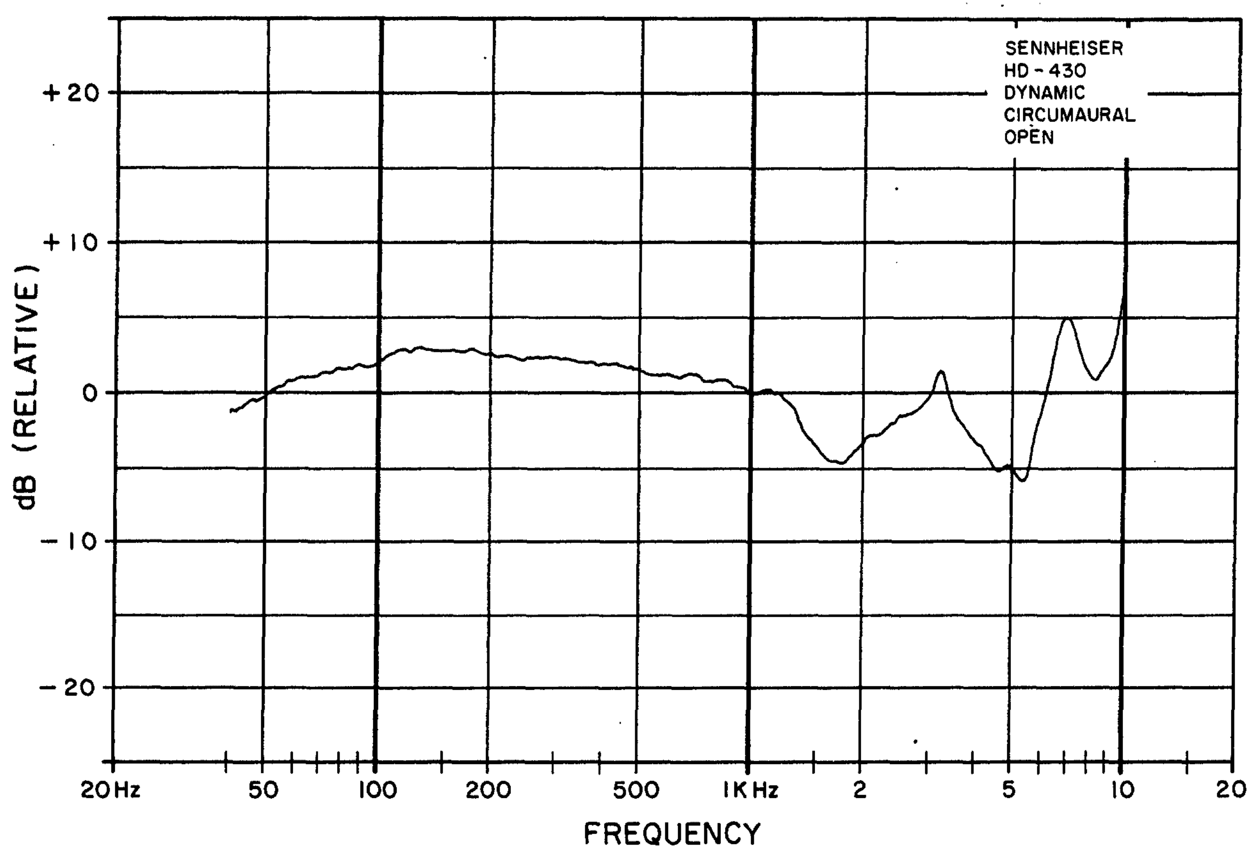

Figure 1. Frequency response of Sennheiser Model HD 430 Headphones: average of 20 responses.

Figure 2 shows the frequency response of an early version of the David Clark headset, model 12507G-20. This sealed-circumaural headphone had been selected for use in SubACS sonar systems. The data are averages of 5 measurements each of the left and right earphone elements of a single headphone. A variation of 28 dB was found between 40 Hz and 10 kHz for that specimen model. A steep drop-off of approximately 30 dB per octave can be seen in Figure 2 beginning at 4 kHz, reaching a maximum at 6 kHz and then improving by 15 dB at a 30 dB per octave rate from 6 to 9 kHz. From 90 Hz to 5 kHz the variation is 10 dB.

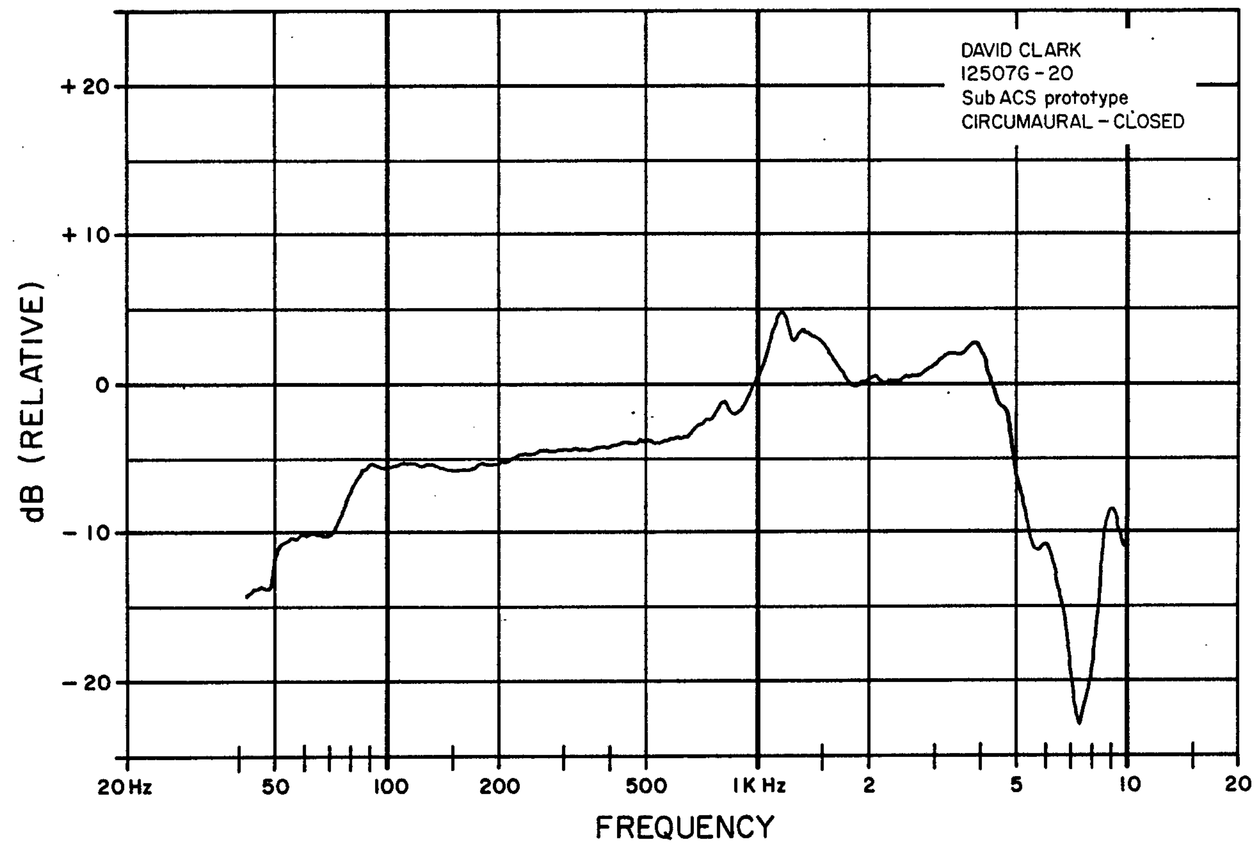

Figure 2. Frequency response of David Clark Model 12507G-20 (prototype) Headphone: average of 10 responses.

Figure 3 shows the average frequency response of two David Clark model 12507G-20 headsets taken from open-stock, sealed cartons. These are now the stock headsets for sonar systems. Five measurements were made on each earphone element of a two-headphone sample, for a total of 20 response curves, which were averaged to produce the single response curve shown. These headphones show a mean variation of 31 dB from 40 Hz to 10 kHz, with roughly a 20 dB notch, maximal at 8 kHz, which begins at 6 and ends at 9 kHz. From 90 Hz to 5 kHz the variation is 23 dB.

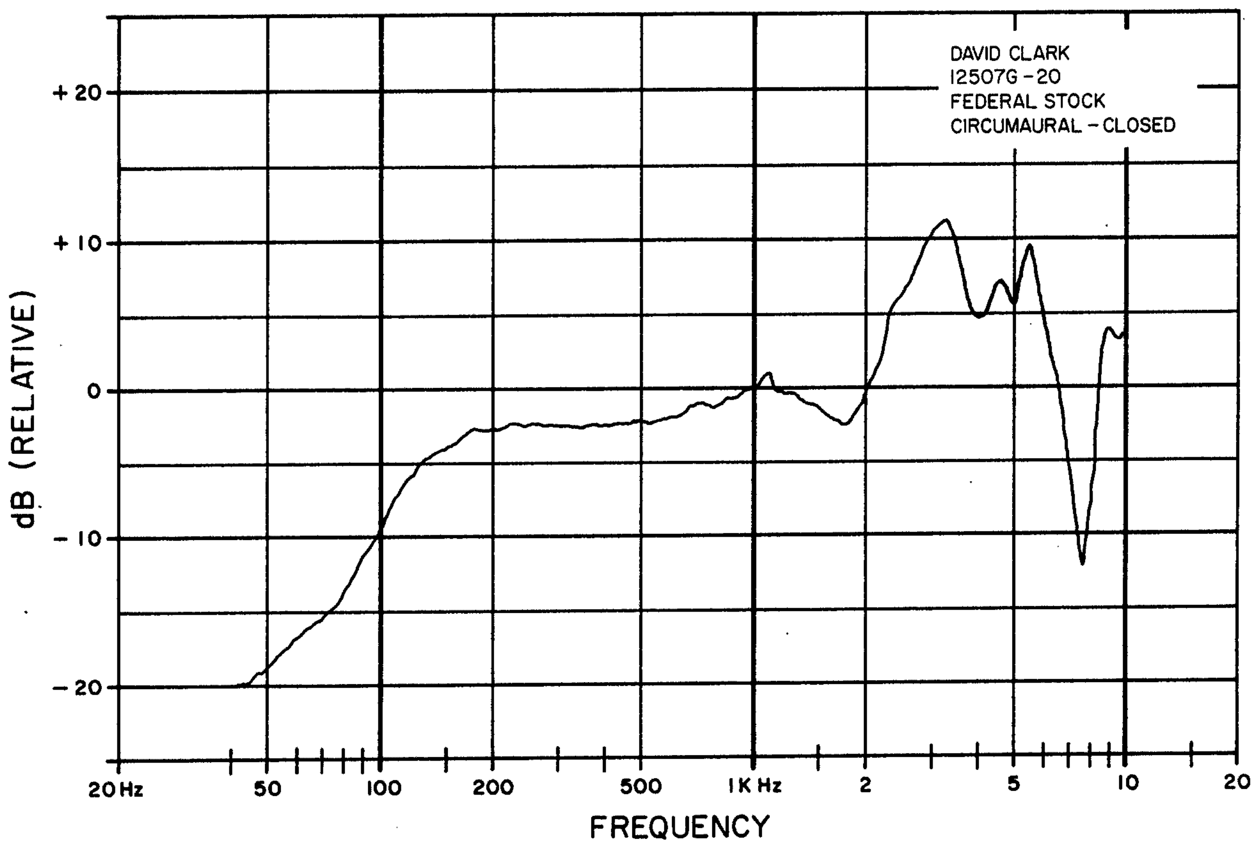

Figure 3. Frequency response of David Clark Model 12507G-20 (Federal Open Stock) Headphones: average of 20 responses.

Similar data for the Koss Pro 4 AAA headset are shown in Figure 4 for comparison (Russotti, et al., 1985). This headset, a sealed-circumaural type, was once used extensively in the fleet in preference to Navy stock sonar headsets. Average data on this headset show a variation of 23 dB from 40 Hz to 10 kHz with a broad notch, from 2.5 to 9 kHz, approximately 17 dB down on either side of a 5 kHz peak. From 90 Hz to 5 kHz the variation is 22 dB.

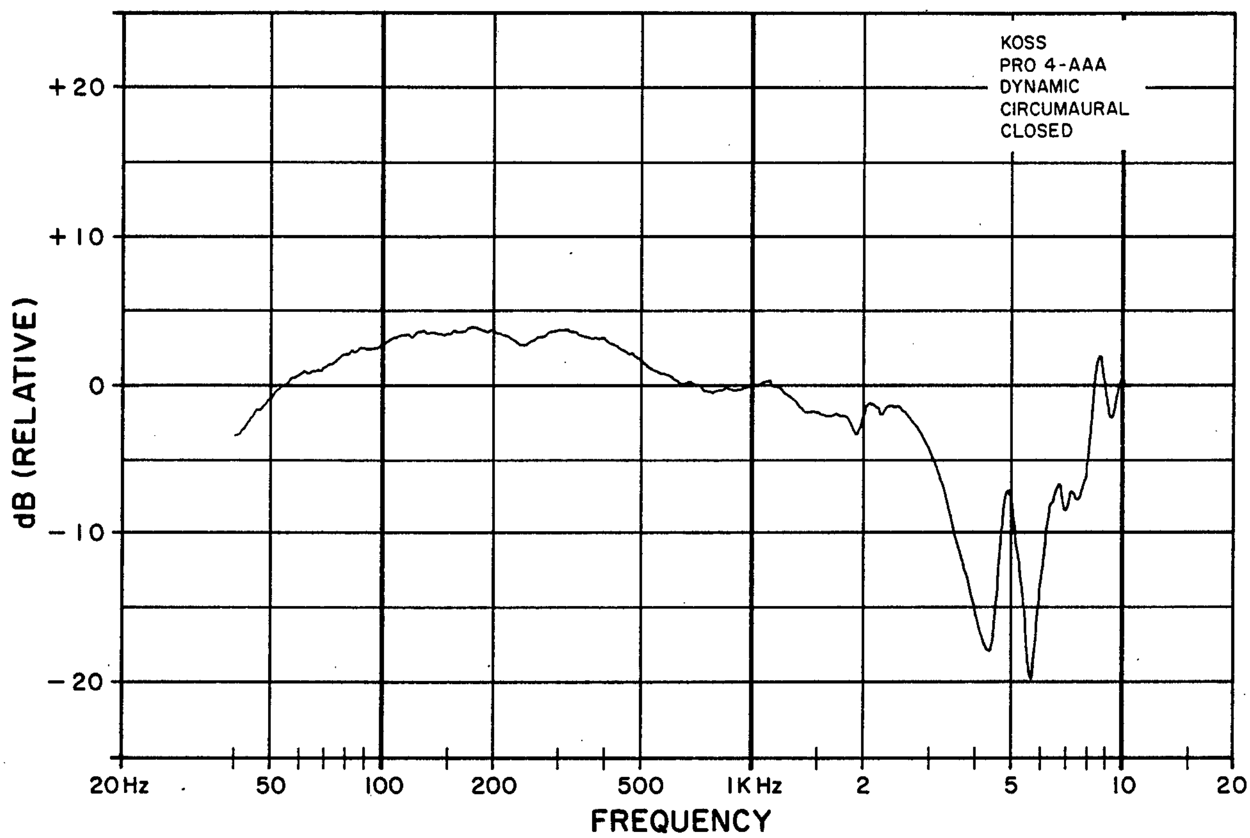

Figure 4. Frequency response of Koss Pro 4 AAA Headphones: average of 20 responses.

Neither the open-stock David Clark Model, nor the Koss headset, can provide optimal information for auditory detection and certainly would not provide optimal information for aural analysis. To the extent that aurally detectable target energy may be present at frequencies that these headsets attenuate, information would be severely reduced in the transfer from electrical to acoustic energy.

Another major concern in headphone selection is the inconsistent low-frequency response found in sealed-circumaural headphones as a result of their inherent need for a proper pressure seal against the head. By its very design, the earphone element in a sealed-circumaural headphone must operate as a pressure transducer. Any acoustic leaks will change its sound pressure output. Figure 5 presents 20 individually corrected frequency-response curves for the Koss, model Pro 4 AAA, headset shown in Figure 4. Despite careful placement under controlled conditions, variations in response of up to 20 dB occurred from 40 Hz to approximately 900 Hz. Figure 6 presents 10 frequency-response curves for the David Clark prototype. Figure 7 presents 20 such curves for the David Clark open-stock version. Apparently, the David Clark, model 12507G-20, is better at minimizing such acoustic leaks. Most of its variation occurred below 200 Hz, though major variations in response (15 dB at 100 Hz) did occur with the tested open-stock model despite careful placement and adjustment of the ear cushions on the measurement device.

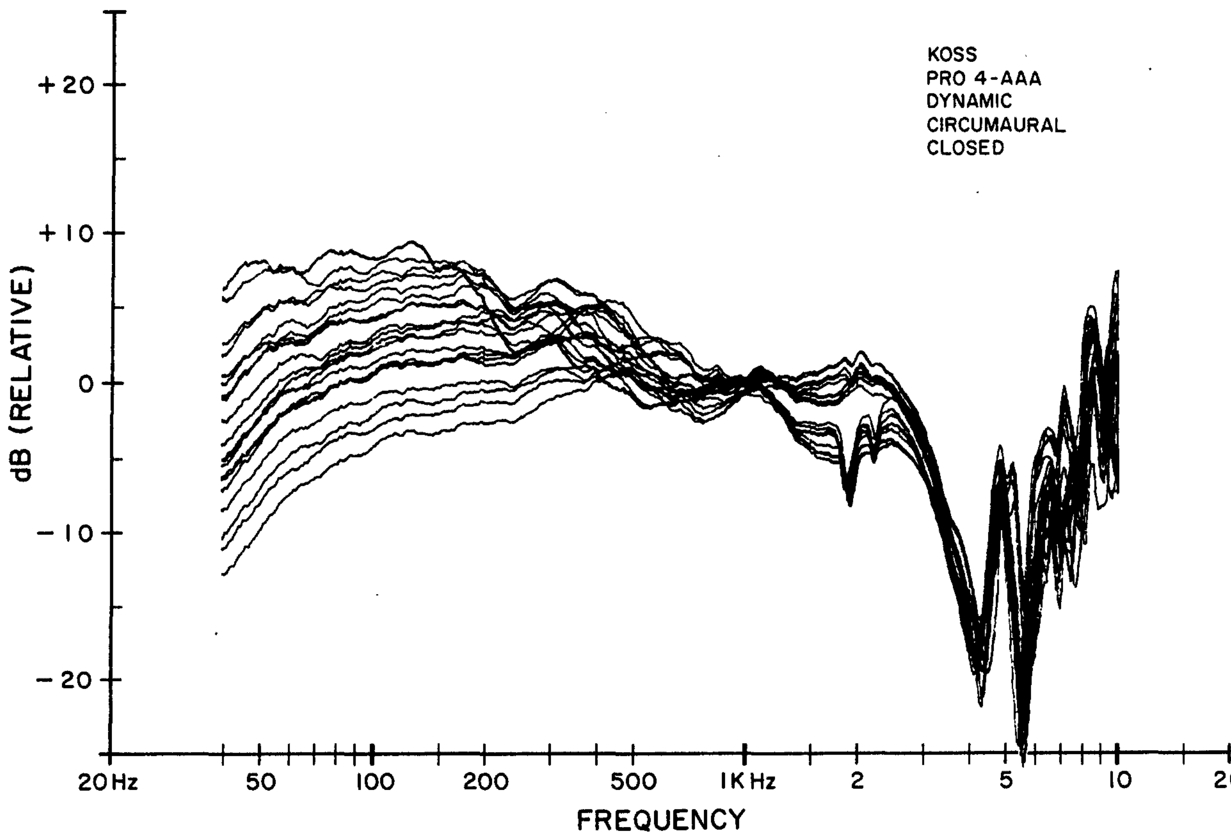

Figure 5. Frequency response of Koss Pro 4 AAA Headphones: 20 individual responses.

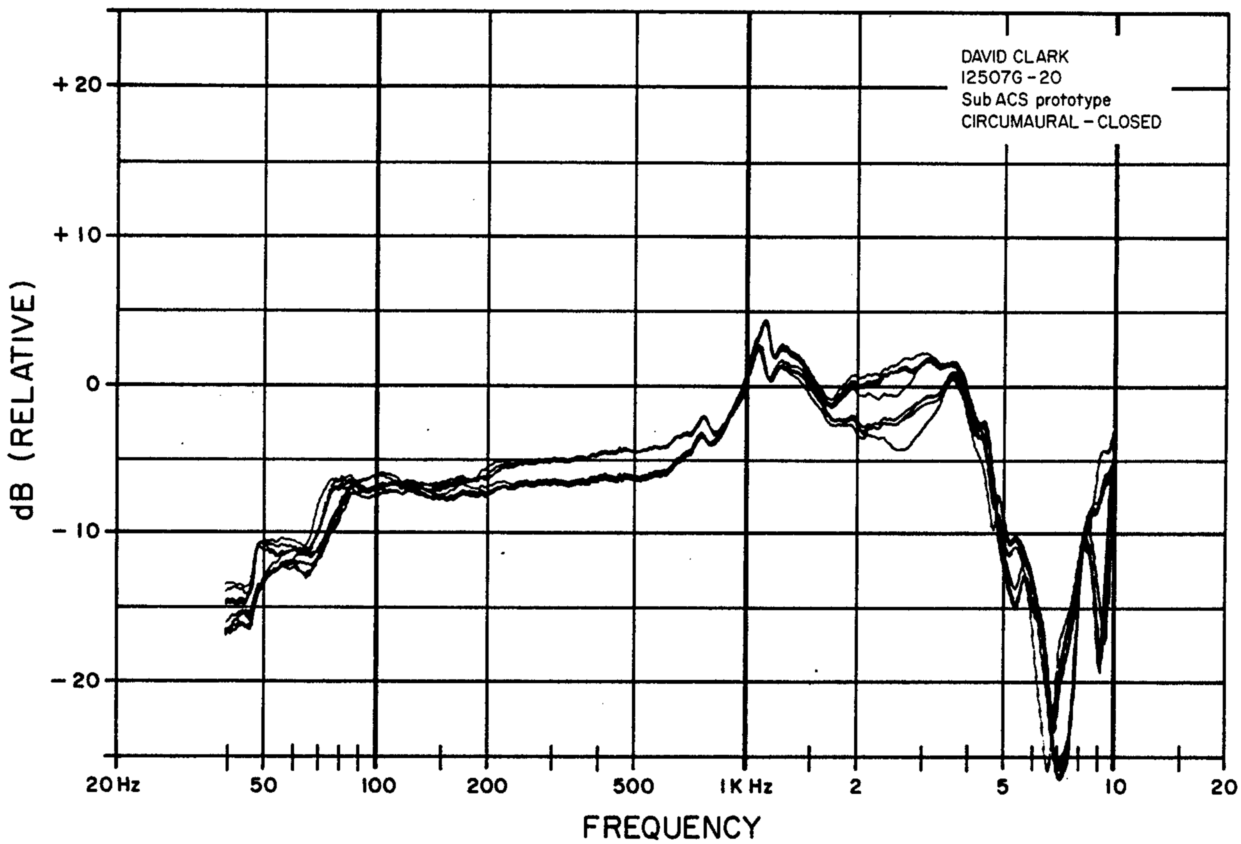

Figure 6. Frequency response of David Clark Model 12507G-20 (prototype) Headphone: 10 individual responses.

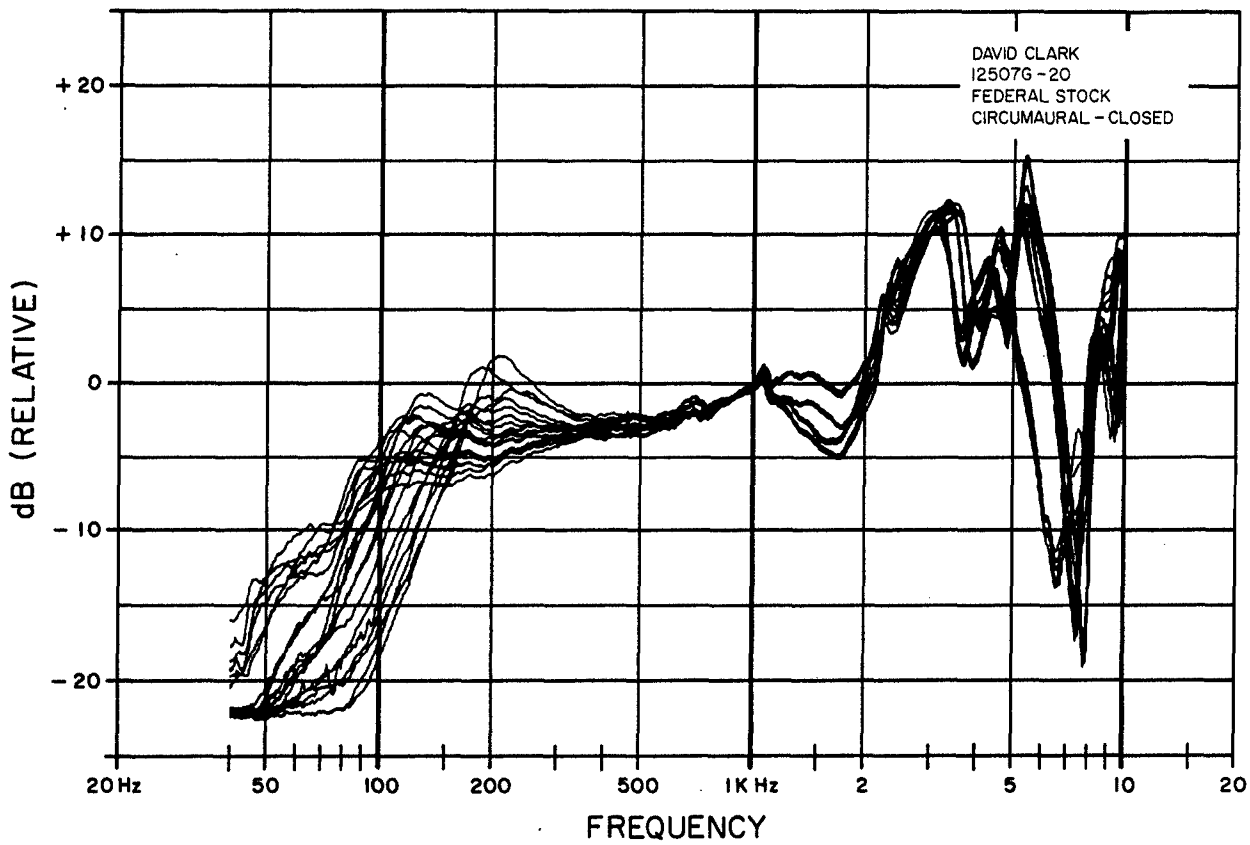

Figure 7. Frequency response of David Clark Model 12507G-20 (Federal Open Stock) Headphones: 20 individual responses.

Of the sealed-circumaural headphones tested, the early production David Clark model provided for SubACS appears to be the most suitable in terms of both average response and freedom from variability due to inadequate or inconsistent seal against the head. However, given the superior frequency response of other headphone designs, and since spectral components at all available frequencies are a potential source of identifying information, sealed-circumaural headphones are certainly not the ideal choice for aural analysis of signals. Our performance data show that accurate transfer of electrical energy from at least 100 Hz and upward is essential even for use only in target detection. Sealed-circumaural headphones suffer from two major problems: first, the natural resonance of the cavity, and second, the low-frequency variability from lack of a proper acoustic-pressure seal. Such variations can be caused by an inconsistent pressure seal against the head, and they increase with deterioration or hardening of the ear cushion. Elaborate electronic solutions to compensate for the diminished sound output that occurs with poor acoustic seal can be devised. A more logical solution would be the overall reduction of airborne noise in sonar workspaces. Such a solution would be in line with a general need to reduce radiated energy and would allow use of more accurate, far more comfortable headphones.

As a final comment, no single current headset is optimal for all sonar applications: communication, detection, and aural analysis. Until a headphone can be produced that has a flat frequency response across the entire auditory bandwidth, the best headphone would be one with the flattest response within the bandwidth of the specific system with which it is to be used. For example, if asked to provide a headphone for a listening system limited to 4 kHz, models other than the Sennheiser HD 430 might provide flatter responses from 40 Hz to 4 kHz. If a headset were available that consistently generated a uniformly flat acoustic output from 20 Hz to 20 kHz, it would be ideal for any system that has lesser bandwidth. No such headphone exists. For the present, we need to consider headsets that provide the flattest response over the broadest anticipated listening range of the entire sonar system. Unfortunately, we are at the other extreme. We are adapting noise-attenuating, communications headsets of limited bandwidth to more critical listening applications where broader bandwidth is essential.

SUMMARY

Broadband detection performance is improved when low-frequency information is extended downward from currently used low-frequency cut-offs. To accommodate such a presentation, system electrical response and headphone frequency-response specifications need to be improved.

Headphone frequency-response data show that sealed-circumaural headsets do not provide the most accurate frequency response. Unfortunately, current noise levels in sonar spaces necessitate their use. The David Clark model obtained from open stock performed much worse than a prototype of this model. Still, of all the sealed-circumaural models tested, it had the least low-frequency variability.

The best solution to selection of headsets for passive sonar detection and aural analysis is reduction of noise in sonar spaces to permit use of open-air headphones. In addition to superior frequency-response accuracy, such headphones provide freedom from low-frequency variations with placement on the head and are far more comfortable for extended wear.

REFERENCES

Russotti, J. S. (1987). (U) The effects of system bandwidth on passive sonar target detection using normal and experimental sonar displays. Naval Submarine Medical Research Laboratory Report 1103. (Secret)

Russotti, J. S., Santoro, T., Haskell, G. B., & Neal, R. (1985). Proposed transfer-function technique for earphone analysis. Naval Submarine Medical Research Laboratory Report #1052.

Russotti, J. S., Haskell, G. B., Neal, R., Santoro, T. P., & Carpenter, S. M. (1985). Frequency response and distortion measurement of headsets for use in auditory sonar displays. Naval Submarine Medical Research Laboratory Report #1066.

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Several closed headsets were evaluated for use by sonar operators. Their frequency response and degree of variability were measured and compared to other headsets which were open to outside noise. The advantages and disadvantages of open and closed headsets are discussed and recommendations made.